LASER ANNEALING METHOD AND LASER ANNEALING DEVICE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a method of crystallizing an amorphous silicon film or a crystalline silicon film formed on an insulating substrate of glass or the like or promoting crystalline performance thereof by performing laser annealing thereto.

2. Description of Prior Art

In recent years researches have widely been carried out on the technology of crystallizing an amorphous semiconductor film or a crystalline semiconductor film (semiconductor film having crystalline performance constituted not by single crystal but polycrystal, microcrystal or the like), that is, a non single crystal silicon film formed on an insulating substrate of glass or the like or promoting the crystalline performance by performing laser annealing in respect of the film. A silicon film is frequently used for the semiconductor film.

Compared with a quartz substrate which has been frequently used conventionally, a glass substrate has an advantage where the substrate is inexpensive and superior in fabrication performance and a substrate having a large area can easily be formed. Further, laser is preferably used in crystallization process since the melting point of the glass substrate is low. Laser can impart high energy only to a non single crystal film without considerably changing temperature of a substrate.

A crystalline silicon film formed by performing laser annealing is provided with high mobility. Further, researches have been carried out on the technology of forming a thin film transistor (TFT) by using the crystalline silicon film. According to the technology, a liquid crystal electro-optic device of a monolithic type where TFTs for pixel driving and for drive circuit are fabricated on one sheet of a glass substrate, can be provided. The crystalline silicon film is constituted by a number of crystal grains and therefore, the film is referred to generally as a polycrystalline silicon film or a polycrystalline semiconductor film.

Further, a method of performing laser annealing by fabricating a pulse laser beam of an excimer laser or the like having a large output into a square spot of several cm square or a linear shape of several mm width × several tens cm on an irradiated face by an optical system and scanning the laser beam (moving an irradiation position of the laser beam relatively in respect of the irradiated face), is preferably used since the method is provided with excellent mass production performance and is industrially excellent.

Particularly, when the linear laser beam is used, high mass production performance can be provided since laser irradiation can be carried out over the entire irradiated face by scanning the laser only in a direction orthogonal to the line direction different from a case of using a laser beam in a spot-like shape where scanning in the forward and rearward direction and in the left and right direction is needed.

Several problems have been posed in performing laser annealing in respect of a non single crystal silicon film by scanning a laser beam of a spot-like shape or a linear shape with a pulse laser beam as a light source.

A particularly serious problem is nonuniformity of effect of laser irradiation in a substrate face. As feature of laser beam, although provision of large energy is pointed out as the most preferable advantage, on the other hand, the pulse laser is provided with a drawback where dispersion of energy for respective shots of pulses is as large as several percent. According to the drawback, when, for example, a liquid crystal display is formed by crystallizing an amorphous silicon film by an excimer laser, there causes an inconvenience where trace of pulse of laser is visualized as it is on picture image.

Such an image failure constitutes a serious drawback in the present age where beautiful picture image is needed. The present invention has been carried out with an object of making inconspicuous or completely eliminating the drawback.

SUMMARY OF THE INVENTION

In order to solve the above-described problem, the inventors have paid attention to an atmosphere of a substrate in irradiating laser, performed laser irradiation under various kinds of atmosphere and investigated differences therebetween.

An amorphous silicon film in which the concentration of hydrogen was controlled was selected as an object of laser irradiation. The hydrogen concentration of a film was set to an order of 10^{20} atoms/cm^3. An excimer laser was used for the laser. The result is shown below.

High energy was needed for crystallizing the film when laser irradiation was performed in an atmosphere of a gas having low thermal conductivity such as nitrogen. Meanwhile, when laser irradiation was performed under a state in which a substrate was subjected to an atmosphere of a gas having high thermal conductivity such as hydrogen or helium, a film having high crystalline performance was obtained by comparatively low energy. Further, the temperature of the substrate in laser irradiation was varied in a range of 200° C. through 400° C. Although comparatively low laser energy was used when the temperature was high, the homogeneity was deteriorated.

The laser irradiation under the atmosphere of the above-described gases only gave rise to a variation in optimum laser energy for crystallization and the homogeneity was not promoted. However, when oxygen was mixed to the atmosphere or only oxygen was used in the atmosphere, the situation-was significantly changed. The optimum energy for crystallization was significantly reduced and further, the homogeneity of the film after laser irradiation was also promoted.

It was found from the above-described experiment that oxygen was very effective in promoting the homogeneity and in reducing the optimum laser energy for crystallization. In FIG. **2**, an investigation was conducted on the crystalline performance of the substrate in view of half width of Raman half value by varying the atmosphere and the laser energy. The lower the value of the half width of Raman half value, the more excellent is the crystalline performance and therefore, the effect of mixing oxygen is quite apparent. Further, it was found by the above-described experiment that the lower the temperature, the more promoted was the homogeneity. Incidentally, the abscissa designates the energy density (mJ/cm^2) and the ordinate designates the half width of Raman half value (cm^{-1}).

Oxygen was particularly effective in laser crystallization when the temperature of the substrate was lowered to the room temperature. Under an atmosphere of a gas not including oxygen, at room temperature, enormous laser energy was needed in crystallization by which the productivity was deteriorated significantly. Further, even in the temperature region of 200° C. or lower, the lower the temperature, the more improved was the homogeneity. The data is shown in FIG. **4**.